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Docket No: YAMAP0801US

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Christine Arndt | February 8, 2006
Christine Arndt | Date

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	Delman Lee et al.
Serial No.:	10/081,916
Filing Date:	February 20, 2002
For:	METHOD AND APPARATUS FOR RECTIFYING A STEREOSCOPIC IMAGE
Examiner:	John B. Strege
Art Unit:	2625
Notice of Appeal:	December 8, 2005

APPEAL BRIEF

Mailstop Appeal Brief-Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

This brief is being submitted in connection with the appeal of the above-identified application.

I. Real Party in Interest

The real party in interest in the present appeal is Sharp Kabushiki Kaisha, the assignee of the present application.

II. Related Appeals and Interferences

Appellants, appellants' legal representatives, and/or the assignee of the present application are unaware of any appeals or interferences which will directly affect, or be directly affected by or have a bearing on the Board's decision in the pending appeal.

III. Status of Claims

Claims 1-42 are pending in the application. Claims 1-21 and 35-38 have been allowed, and claims 23 and 31 have been indicated as being allowable if rewritten in independent form. Claims 22, 24-30, 32-34 and 39-42 stand finally rejected and are the subject of this appeal.

IV. Status of Amendments

On October 26, 2005, Applicant filed an amendment after final amending claim 23. For purposes of appeal, the amendment was entered.

V. Summary of Claimed Subject Matter

A. Background

To create a stereoscopic display, two images are acquired using a stereoscopic image capture device that provides two image capture devices. One image capture

device (known as the "left image capture device") captures an image corresponding to the image that would be seen by the left eye of an observer, and the other image capture device (known as the "right image capture device") captures an image corresponding to the image that would be seen by the right eye of an observer. The two images thus acquired are known as a pair of stereoscopic images, or stereoscopic image pair. When the two images are displayed using a suitable stereoscopic display device, a viewer perceives a three-dimensional image.

One problem with conventional stereoscopic displays is that stereoscopic images can be uncomfortable to view, even on high quality stereoscopic display devices. One cause of discomfort is the presence of vertical disparity within a stereoscopic image pair. Vertical disparity means that the image of an object in one of the stereoscopic images has a different vertical position than the image of the same object in the other stereoscopic image. Vertical disparity arises due to many kinds of mis-alignment of the camera systems, and causes discomfort to a viewer. Image rectification is a process for eliminating vertical disparity between the two images of a stereoscopic image pair, thereby making the resultant stereoscopic image more comfortable to view.

B. Description

Referring to Fig. 6 (reproduced below), a method of rectifying a stereoscopic image that includes first and second captured images obtained from first and second image capture devices is shown. Fig. 6, portions of which correspond to claims 22 and 39, illustrates an entire rectification process from initial capture of the image pair to display of the rectified image on a suitable stereoscopic imaging device.

The method is intended for use with a pair of captured images that form a stereoscopic image pair, and this pair of images forms one input to the method. A suitable image capture device, for example, is a stereo-camera including of a pair of digital cameras.

At step 11, a stereoscopic image pair consisting of a left image and a right image pair is captured with a stereoscopic camera set-up. At step 12, pixel correspondences between the left and right images are detected using any standard technique.[1] That is, pairs of image points are established (one point in the left image and one point in the right image) that are images of a unique three-dimensional point in the object scene (i.e., each pair consists of a point in one image and a corresponding point in the other image). If there is vertical disparity between the two images, this will become apparent during correspondence detection. The correspondence of the point features is established using known robust statistical methods, which reject chance correspondences that do no fit into the epipolar geometry governed by the majority of the correspondences.[2] At step 18 these correspondences are used to compute a 'fundamental' matrix relating the two images.[3]

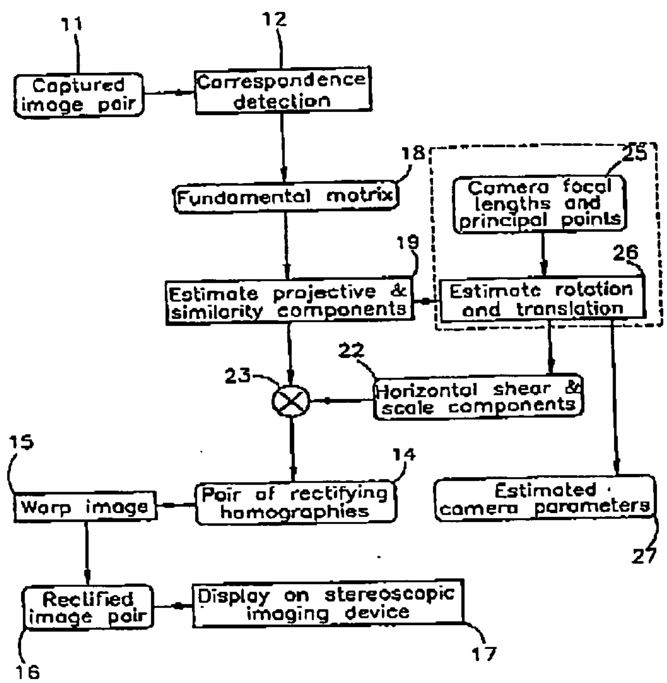

FIG 5

1. Page 29, line 20-page 30, line 5 of the application. Steps 11, 12, 18 and 19 of Fig. 6 are identical to the respective steps of Fig. 5. The specification does not explicitly discuss these steps with respect to Fig. 6 and, thus, reference is made here to the description relating to Fig. 5.

2. Page 48, lines 12-21 of the application.

3. Page 30, lines6-7 of the application.

The fundamental matrix relates a point x_{0j} in the left image of an image pair to the corresponding point x_{1j} in the right image of the image pair. For example, the camera matrices can be given by

$$P_0 = K_0[I|0]$$

$$P_1 = K_1\left[R^T|-R^T t\right]$$

where K_i is a 3x3 calibration matrix of the i_{th} camera (i = 0 for the left camera and i = 1 for the right camera), R is a 3x3 rotation matrix and t is a translation 3-vector. R and t are respectively the rotation and translation of the right camera (i = 1) relative to the left camera (i = 0). Assuming that skew is negligible, the calibration matrix K_i is

$$K_i = \begin{bmatrix} f_i & 0 & p_i \\ 0 & f_i & q_i \\ 0 & 0 & 0 \end{bmatrix}$$

where f_i is the effective focal length and (p_i,q_i) is the principal point in the image plane. The 3x3 fundamental matrix F relates to the projective and similarity components of the rectifying transformation, as indicated by step 18.[4]

As recited in claims 22 and 39, first and second rectification transformations are determined and are used for rectifying a respective one of the first and second images (obtained in step 11) so as to reduce vertical disparity. The first and second rectification transforms are determined so that they correspond to a virtual alignment to a parallel camera set-up. Moreover, claims 22 and 39 further recite that the determination of the first and second rectification transformations includes calculating a

4. Page 46, line 12-page 47, line 5 of the application.

shear component such that a final matrix is a combination *of a rotation and a translation* and *at least one camera parameter*. These features are discussed in more detail below.

At step 19, the correspondence information is used to determine a component of the rectification transformations (the "projective and similarity components") which will be used to rectify the two images. This component of the overall rectification transformations is intended to remove vertical disparity from the rectified image pair.[5]

In the embodiment of Fig. 6 (portions of which correspond to claims 22 and 39), it is assumed that the focal length and principal points of the left and right cameras are known (e.g., from tests made during manufacture) and this data is input at step 25. At step 26, the rotation and translation operators R and t are estimated from the focal length and principal points of the cameras, and from the projective and similarity components of the transformations. This is done by decomposing the final matrix to be calculated into several parts, most of which are known. Standard mathematical methods are then used to solve for the unknown quantities.[6]

Once the rotation and translation operators have been estimated, then at step 22 the horizontal shear and scaling components of the rectification transformation are determined from the known focal lengths and principal points of the cameras, and from the estimated rotation and translation operations. The pair of rectification transformations are then found by combining the projective and similarity component of the transformations (step 19) with the horizontal shear and scale components (step 22 with data from steps 25 and 26). If desired, the estimated camera rotation and translation operations can be output at step 27.

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5. Page 30, lines 11-16 of the application.

6. Page 36, line 18-page 37, line 2 of the application.

The invention of claims 22 and 39 is particularly suited for processing a stereo image pair captured using a stereo camera set-up where the intrinsic camera parameters are accurately known, but the extrinsic parameters are not accurately known - that is, where each camera is individually of high quality, and the deviation of the stereoscopic camera set-up from a parallel camera set-up occurs primarily in the orientation of one camera relative to the other.

In the invention of claims 22 and 39, the choice of the horizontal shear and scaling components of the transformations is constrained to ensure that the resultant pair of rectifying transformations corresponds to a virtual alignment to a parallel camera set-up. To ensure this, the ***shear component*** is calculated from an equation formulated such that the final matrix is *a combination of a rotation and a translation and the internal camera parameters*,[7] as recited in claims 22 and 39.

Criteria used to determine a shear component in prior art methods can lead to rectification transformations that do not correspond to a virtual alignment to a parallel camera setup. According to the invention of claims 22 and 39, the criterion for the determination of the shear component relates to what is physically probable. The shear component is chosen such that the rectifying homography corresponds to virtually rotating the camera. Furthermore, the shear terms are constrained using *a priori* knowledge of the intrinsic and extrinsic parameters of the camera. This *a priori* knowledge is expressed in terms of probability densities.[8]

After the projective and similarity component of the transformation and the horizontal shear and scaling component of the transformation have been determined, they are combined at step 23 to produce the pair of rectifying transformations at step 14. Once determined, the rectification transformations may be used immediately, or

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7. Page 37, line 4-page 38, line 12 of the application.

8. Page 56, line 21-page 57, line 15 of the application.

they may be output and/or stored for subsequent use. When the rectification transformations are used, they are used to warp the captured image pair in a conventional manner at step 15, to produce a rectified image pair at step 16. The end product is a rectified image pair, with no or substantially no vertical disparity, which should be much more suitable for comfortable stereoscopic viewing than the original captured image pair.

The rectified image pair may be displayed on a suitable stereoscopic display device at step 17, for direct viewing by an observer. Alternatively, the rectified image pair can be stored for future use.

VI. Grounds of Rejection to be Reviewed on Appeal

A. Whether claims 22, 24-27, 33-34, and 39-40 are patentable under 35 U.S.C. §103(a) over IEEE article by *Courtney et al.* (A Hardware Architecture for Image Rectification and Ground Plane Obstacle Detection, IEEE, 1992, hereinafter *Courtney*) in view of U.S. Patent No. 6,608,923 to *Zhang et al.* (hereinafter *Zhang*).

B. Whether claims 28-30, 32 and 41-42 are patentable under 35 U.S.C. §103(a) over *Courtney* in view of *Zhang* in further view of U.S. Patent No. 5,142,357 to *Lipton et al.* (hereinafter *Lipton*) and Applicant's admitted prior art (AAPA).

VII. Argument

Claims 22, 24-30, 32-34 and 39-42 stand finally rejected as being unpatentable over the applied art. For the following reasons, it is respectfully submitted that the claims are patentable over the applied art and the final rejection should be withdrawn.

A. Claim 24

Claim 24 stands rejected rejected under 35 USC §103(a) as being unpatentable over *Courtney* in view of *Zhang*. Reversal of the rejection is respectfully requested for at least the following reasons.

In the Advisory Action mailed November 15, 2005, claim 23 was indicated as being allowable if rewritten in independent form including all the limitations of the base claim and any intervening claims. Since claim 24 depends from claim 23, claim 24 is allowable for at least the same reasons.

Accordingly, reversal of the rejection of claim 24 is respectfully requested.

B. Claims 22, 25-30, 32-34 and 39-42

1. Claims 22, 25-27, 33-34 and 39-40

Claims 22, 25-27, 33-34, and 39-40 stand rejected under 35 USC §103(a) as being unpatentable over *Courtney* in view of *Zhang*. Reversal of the rejection is respectfully requested for at least the following reasons.

Independent claims 22 and 39 recite that a *shear component* is calculated such that a final matrix is a *combination* of a *rotation and a translation and at least one internal camera parameter*. The Examiner admits that *Courtney* does not teach this feature. However, the Examiner contends that *Zhang* does teach this feature, and cites to the Abstract, column 6, lines 55-65 and Fig. 7 of *Zhang*.[9]

Zhang describes a method for rectification of images so as to achieve minimal distortion, wherein images are rotated and translated, and then a shearing transform is applied to scale and translate the images in the horizontal direction.[10] *Zhang*, however, has not been found to teach or suggest *calculating a shear component such that a final*

9. Page 3, first full paragraph of the Office Action

10. Fig. 7 of *Zhang*.

matrix is a <u>combination</u> of a rotation and a translation <u>and</u> at least one internal camera parameter, as recited in claims 22 and 39.

Applicants respectfully submit that *Zhang* does not make up for the deficiencies in *Courtney*. As will be appreciated in view of the following, Applicants respectfully submit that *Zhang* does not teach or suggest determining the first and second rectification transformation so that the first and second rectification transformations correspond to a virtual alignment to a parallel camera set-up, wherein determining the first and second rectification transformation includes *calculating a <u>shear component</u> such that a final matrix is a <u>combination</u> of a rotation and a translation <u>and</u> at least one internal camera parameter*. Thus, even if the teachings of the references were combined as proposed by the Examiner, the invention of claims 22 and 39 would not result.

Referring now to the cited portions of *Zhang*, the Abstract simply states that affine transforms, which are used to compute two-dimensional projective transforms or homographies, can include a first transform and an optional second transform for image rectification. Fig. 7 of *Zhang* (reproduced at right) illustrates the steps for providing rectification of images from a projective transform and fundamental matrix. The affine

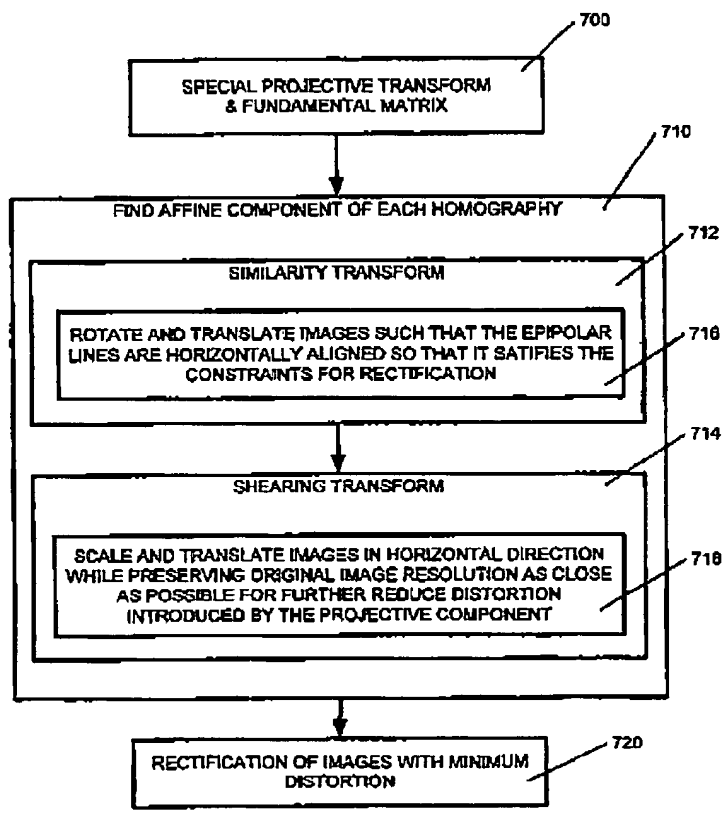

FIG. 7

component of each homography is obtained by performing a similarity transform (step 712), wherein the affine component is based on images that are rotated and translated such that epipolar lines are horizontally aligned to satisfy the constraints for rectification. Then, a shearing transform is applied (step 714), wherein images are scaled and translated in the horizontal direction while attempting to preserve the original image resolution (step 718). Neither the Abstract nor Fig. 7, however, have been found to teach or suggest that a *shear component* is calculated such that a final matrix is a *combination* of a *rotation and a translation* *and* *at least one internal camera parameter*, as recited in claims 22 and 39.

Further, column 6, lines 55-65 of *Zhang* state that if *intrinsic parameters of a camera are known, the images are calibrated*, and the fundamental matrix becomes the essential matrix. More importantly, however, the cited portion states that the invention is applicable to both calibrated or uncalibrated image pairs. In other words, the invention disclosed in *Zhang* is applicable to systems wherein the intrinsic camera parameters are known (calibrated images) or unknown (uncalibrated images). Moreover, intrinsic camera parameters do not appear in any of the formulae of *Zhang*. Thus, it follows that the method of *Zhang* can be applied without knowledge of intrinsic camera parameters (e.g., uncalibrated images).

Additionally, *Zhang* has not been found to teach or suggest calculating the *shear component* such that a final matrix is a ***combination*** *of a rotation and a translation* ***and*** *at least one internal camera parameter*, as recited in claims 22 and 39. This is logical, as the method of *Zhang* is applicable to uncalibrated images (images obtained without knowledge of intrinsic camera parameters) as well as calibrated images. Thus, intrinsic camera parameters are not required to implement the method of *Zhang*. *Zhang* also has not been found to teach or suggest how one would use intrinsic camera parameters to determine the transformations, nor are they shown with respect to the shearing transform.

Accordingly, *Courtney* in view of *Zhang* has not been found to teach or suggest that a *shear component* is calculated such that a final matrix is a *combination* of a rotation and a translation *and* at least one internal camera parameter, as recited in claims 22 and 39.

Further, in the Advisory Action dated November 15, 2005, the Examiner, with the exception of claim 23, maintains the rejections of the final Office Action. Additionally, the Examiner states that *Courtney* discloses using internal camera parameters for computing matrix elements, and that *Zhang* teaches that a fundamental matrix is rotated and translated, such that it satisfies the constraints for rectification.[11] According to the Examiner, it would have been obvious to combine *Courtney* and *Zhang* to arrive at the invention of claim 22.

While section 2 of *Courtney* does discuss the use of camera parameters, *Courtney* has not been found to teach or suggest that a *shear component* is calculated such that a final matrix is a combination of a rotation and a translation and at least one internal camera parameter. Instead, *Courtney* simply states that *matrix elements* may be computed from camera calibration parameters. There is no discussion in section 2 of *Courtney* with respect to calculating a *shear component*.

Moreover, and as discussed above, none of the formulae in *Zhang* include camera parameters. Further, while *Zhang* does discuss intrinsic camera parameters, the disclosure of *Zhang* indicates that the method can be implemented with or without knowledge of the camera parameters.[12] Thus, one viewing *Zhang* would have no motivation to combine the camera parameters of *Courtney* (which do not relate to a

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11. Section 11 of the Advisory Action dated November 15, 2005.

12. See column 6, lines 55-65 of *Zhang* and argument on pages 11-12.

shear component), with the method of *Zhang* (which does not need camera parameters).

Accordingly, reversal of the rejection of claims 22 and 39 is respectfully requested.

Claims 25-27, 33-34, and 40 directly or indirectly depend from claim 22 or 39 or claim 39 and, therefore, can be distinguished from the cited art for at least the same reasons.

Accordingly, reversal of the rejection of claims 25-27, 33-34, and 40 is respectfully requested.

2. ***Claims 28-30, 32 and 41-42***

Claims 28-30, 32 and 41-42 are rejected under 35 USC §103(a) as being unpatentable over *Courtney* and *Zhang* in further view of U.S. Patent No. 5,142,357 to *Lipton et al.* (hereinafter *Lipton*) and Applicant's admitted prior art (AAPA). Reversal of the rejection is respectfully requested for at least the following reasons.

Claims 28-30 and 32 directly or indirectly depend from independent claim 22, while claims 41-42 directly or indirectly depend from independent claim 39. As discussed above, claims 22 and 39 can be distinguished from *Courtney* and *Zhang*.

Lipton is cited for teaching the use of a data processor and that a stereoscopic camera can be used for video or still images.[13] Neither *Lipton* nor the AAPA, however, have been found to make up for the above-noted deficiencies of *Courtney* and *Zhang*.

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13. Page 5, last two paragraphs of the Office Action dated August 8, 2005.

Thus, claims 22 and 39 can be distinguished from *Courtney*, *Zhang*, *Lipton* and the AAPA.

Since claims 28-30, 32 and 41-42 depend from one of the above independent claims, they can be distinguished from the cited art for at least the same reasons.

Accordingly, reversal of the rejection of claims 28-30, 32 and 41-42 is respectfully requested.

Conclusion

In view of the foregoing, appellant respectfully submits that the claims are patentable over the applied art and that the final rejection should be reversed.

Respectfully submitted,

RENNER, OTTO, BOISSELLE & SKLAR

Kenneth W. Fafrak
Registration No. 50,689
1621 Euclid Avenue
Cleveland, Ohio 44115
(216) 621-1113

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VIII. Claims Appendix

22. A method of rectifying a stereoscopic image comprising first and second images captured using first and second image capture devices, the first and second image capture devices forming a stereoscopic image capture device, the method comprising the step of;

determining first and second rectification transformations for rectifying a respective one of the first and second images so as to reduce vertical disparity; characterised in that the method comprises determining the first and second rectification transformation so that the first and second rectification transformations correspond to a virtual alignment to a parallel camera set-up, wherein determining the first and second rectification transformation includes calculating a shear component such that a final matrix is a combination of a rotation and a translation and at least one internal camera parameter.

24. A method as claimed in claim 23 wherein the statistics of the parameters of the stereoscopic image capture device relate to the alignment of the first image capture device relative to the second image capture device.

25. A method as claimed in claim 22 wherein the step of determining the first and second rectification transformations comprises:

determining a first component of each of the first and second rectification transformations, the first component of the first rectification transformation and the first component of the second rectification transformation substantially eliminating vertical disparity from the rectified image pair; and

determining a second component of each of the first and second rectification transformations so that the first and second rectification transformations correspond to a virtual alignment to a parallel camera set-up.

26. A method as claimed in claim 25 and further comprising the step of using statistics of the parameters of the stereoscopic image capture device in the step of determining the first and second rectification transformations wherein the statistics of the parameters of the stereoscopic image capture device are used in the step of determining the second components of the first and second rectification transformations.

27. A method as claimed in claim 25 wherein the statistics of the parameters of the stereoscopic image capture device relate to the alignment of the first image capture device relative to the second image capture device.

28. A method as claimed in claim 22 wherein the first captured image and second captured image comprise a still stereoscopic image.

29. A method as claimed in claim 22 wherein the first captured image and second captured image comprise a frame of a stereoscopic video image.

30. A method as claimed in claim 29 and comprising the steps of:

determining first and second rectification transformations for a first frame of the stereoscopic video image using a method as defined in claim 22; and

rectifying subsequent frames of the stereoscopic video image using the first and second rectification transformations determined for the first frame of the stereoscopic video image.

32. A method as claimed in claim 29 and comprising the steps of:

determining first and second rectification transformations for each frame of the stereoscopic video image using a method as defined in claim 22; and

rectifying each frame of the stereoscopic video image using the first and second rectification transformations determined for that frame.

33. A method as claimed in claim 22 and comprising the further step of rectifying the first and second captured images using a respective one of the first and second rectification transformations.

34. A method as claimed in claim 33 and comprising the further step of displaying the first and second rectified images on a stereoscopic display device for viewing by an observer.

39. An apparatus for rectifying a stereoscopic image comprising first and second images captured using first and second image capture devices, the first and second image capture devices forming a stereoscopic image capture device, the apparatus comprising:

means for determining first and second rectification transformations for rectifying a respective one of the first and second images so as to reduce vertical disparity, the first and second rectification transformations corresponding to a virtual alignment to a parallel camera set-up, wherein determining the first and second rectification transformation includes calculating a shear component such that a final matrix is a combination of a rotation and a translation and at least one internal camera parameter.

40. An apparatus as claimed in claim 39 and further comprising means for rectifying the first and second captured images using a respective one of the first and second rectification transformations.

41. An apparatus as claimed in claim 39 and comprising a programmable data processor.

42. A storage medium containing a program for the data processor of an apparatus as defined in claim 41.

IX. Evidence Appendix

None

X. Related Proceedings Appendix

None